Journal of Forensic and Legal Medicine 23 (2014) 70–75

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

Sexing based on measurements of the femoral head parameters on pelvic radiographs

Akhlaghi Mitra, MD, Associate Professor, Member of Research Center [a,b],
Bakhtavar Khadijeh, MD, Assistant Professor [c],
Allahyar Parsa Vida, MD, Specialist in Forensic Medicine [a,*],
Razavi Nouri Ali, MD, General Practitioner [d],
Mehdizadeh Farzaneh, MD, Specialist in Forensic Medicine [a],
Vasheghani Farahani Maryam, MD, Specialist in Forensic Medicine [a],
Yousefinejad Vahid, MD, Specialist in Forensic Medicine [a]

[a] Forensic Medicine Department, Faculty of Medicine, Tehran University of Medical Sciences, Tehran, Iran
[b] Legal Medicine Organization of Iran, Tehran, Iran
[c] Radiology Department, Faculty of Medicine, Tehran University of Medical Sciences, Tehran, Iran
[d] Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Article history:
Received 31 May 2013
Received in revised form
12 December 2013
Accepted 19 January 2014
Available online 6 February 2014

Keywords:
Femur
Sexing
Forensic identification
Femoral head diameter
Femoral neck width
Collo-diaphysial angle

ABSTRACT

Background and aim: Previous studies have shown that the collo-diaphysial angle varies by race and sex in different populations. This study was performed to compare the femoral head parameters in the two sexes using pelvic radiography in Iranian adults during the August 2011 to August 2012 period.
Materials and methods: This cross-sectional study was done on 100 male and 100 female. After taking hip radiography, collo-diaphysial angle, maximum femoral head diameters and minimum femoral neck width were measured on both sides. Dominant hand, height, weight and body mass index were also recorded. Data were analyzed using SPSS software. Sex differences were tested using independent *t*-test and ROC curve.
Results: The mean of the right and left maximum femoral head diameters and the minimum width of the femoral neck were significantly higher in men than in women ($p < 0.001$). The mean of the right collo-diaphysial angle of the femur was significantly higher in men than in women ($p = 0.01$), but there was no significant difference between the left collo-diaphysial angle in the two sex. The accuracy of sex prediction with the right and left maximum femoral head diameter was 78%. This figure is 77% for the right and left minimum femoral neck widths and 59% for the right collo-diaphysial angle.
Conclusion: If only the proximal part of the femur is available, the sex can be predicted with a relatively high accuracy by taking a radiograph. In our study, the evaluation of the collo-diaphysial angle was not very helpful in sexing.

1. Introduction

A variety of diagnostic markers for sexing in human remains have been considered by forensic medicine specialists.[1] Several anatomical structures have been examined for determining the identity and sex of human being including the skull, pelvis and long bones.[1] Due to their high durability, femoral bones are the most useful long bones in sexing. Several factors including femoral length, femoral head diameter and width and angle of the femoral neck have been used for sexing,[1] however, body parts and dimensions vary considerably by age and sex among various races and ethnic groups.[2]

Previous studies have shown higher figure of femoral head diameter[1,3,4] and femoral neck width[3,5] in men compare than women.

The evolution of man and his anatomically standing position on both feet leads to changes in the structures making up the hip. The collo-diaphysial angle is an important factor for hip stability and normal walking.[2] Previous studies have shown that the angle is different based on ethnicity, sex and age.[2,6–9] The obtuse angle is smaller in women mainly due to their wider pelvis and shorter femur.[10] This angle, on average, declines from 150° to 120° at the end of development, but does not change after maturation.[11]

* Corresponding author. Tel.: +98 21 66405588.
E-mail address: vida.allahyarparsa@gmail.com (A.P. Vida).

1752-928X/$ – see front matter
http://dx.doi.org/10.1016/j.jflm.2014.01.004

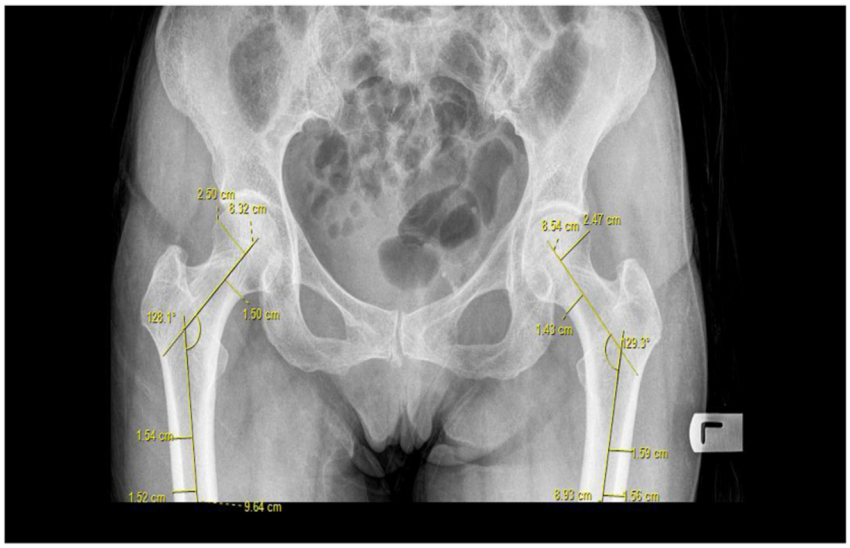

Fig. 1. Measurement of parameters of the femoral Head in a female sample.

Alonso and colleagues showed that the collo-diaphysial angle in men and women with hip fracture was significantly larger than the control group.[12] Subsequent studies in Africa and Europe demonstrated the regional diversity and sex diversity for this angle.[2,13–15] The sexual dimorphism of the angle is used in determining the sex in skeletal remains.[2,3,9,13]

Despite the importance of this angle and extensive studies on different ethnic groups, few studies have been published from Asia.[16–19] Anthropometric parameters of some bones such as the clavicle and the radius in sexing have been evaluated in previous studies in Iran[20,21] but so far, no study has been published in this field from Iran. This study was conducted to compare the femoral head parameters between the two sexes using pelvic radiography in Iranian adults.

2. Material and methods

This was a cross-sectional study. The study population consisted of Iranian adults (20 years of age and older) who were referred to the radiologic department of Sina Hospital in Tehran for hip radiography from August 2011 to August 2012 ($n = 248$). The sample size was 200 (100 men and 100 women) and convenience sampling was conducted using the available samples. Samples were enrolled after providing informing about this study and obtaining written consent.

Patients with the following characteristics were excluded from the study: bone diseases ($n = 1$) or fractures ($n = 41$), congenital ($n = 1$) or acquired skeletal anomalies ($n = 2$) which could have an influence on bone growth, the impossibility to evaluate the angle due to femoral anteversion ($n = 1$) or undesirable stereotypes (radiographs which taken with different method) ($n = 0$), those without valid ID ($n = 0$), chromosomal abnormalities ($n = 0$), hermaphrodism ($n = 0$), and a history of hip or knee arthroplasty ($n = 2$).

Pelvic radiographs were taken for all participating subjects using a radiological device by a qualified technician. The X-ray film was placed one inch below the inguinal ligament in a supine position, then the foot was placed in 15° medial rotation and the X-ray was taken. Radiographs were entered into the PACS[a] system to determine the axis of the femoral neck, the maximum femoral head diameter and the minimum width of the femoral neck by means of the system software. Their midpoints were determined and were connected with a line. To determine the midpoints of femoral head according to Bagaria et al.,[19] three random points on the femoral head were determined on X-ray and connected with two lines then perpendicular bisector of these two lines was drawn and intersection point of them considered as femoral head midpoint. To determine the axis of the femoral shaft, the transverse diameter of the femoral shaft was determined at two points; one below the lesser trochanter and the other in a lower point in diaphysis. The midpoints of the two diameters were then determined and connected by a line. The obtuse angle (interior) between these two axes was measured as the collo-diaphysial angle and the measurements were performed according to Igbigbi's method.[2]

Collo-diaphysial angle, maximum femoral head diameter and minimum femoral neck width were recorded after performing pelvic X-rays and viewing the graph in the PACS system by three different observers independently and measuring the parameters by the PACS software system (Fig. 1), observers were blinded to the measurements of their colleague. The dominant hand, height, weight and body mass index were also recorded. Intra-rater reliability was tested using the intra-class correlation coefficient (ICC).

The collected data was analyzed using SPSS software version 13 by means of descriptive statistical analysis (Frequency-descriptive). Sex differences were tested using independent *t*-test and ROC curve.

3. Results

The mean age of the sample was 39.2 years (the inter-quartile range was 25–49.7 years) with a mean age of 34.6 years (the inter-quartile range was 24–41.5 years) in men and 43.9 years (the inter-quartile range was 28–56.7 years) in women. Twelve men (12%) and 8 women (8%) were left-handed. Reader reliability was good for all collo-diaphysial angle (intra-class correlation coefficient [ICC] = 0.88–0.94).

The mean of the right and left maximum femoral head diameters and the minimum width of the femoral neck were significantly higher in men than in women ($p < 0.001$). The mean of the

[a] Picture Archiving and Communication System.

Table 1
Comparison of the measured femoral head parameters in both sexes.

	Male					Female				
	Num	Mean	SD	Min	Max	Num	Mean	SD	Min	Max
Right maximum femoral head diameter (mm)*	100	57	3.1	48	66.8	100	50.6	2.8	44.2	59
Right minimum femoral neck width (mm)*	100	38.6	2.6	33.2	46.4	100	32.9	2.7	26.6	41.2
Right collo-diaphysial angle (°)*	100	127.5	5.3	117	141.6	100	125.4	6	110.1	138.8
Left maximum femoral head diameter (mm)*	100	57	2.8	52.2	67.8	100	50.3	2.9	45	58.8
Left minimum femoral neck width (mm)*	100	38.8	2.6	32.6	47	100	32.9	3.2	15.2	39.6
Left collo-diaphysial angle (°)	100	127.6	5.6	114.3	143.5	100	126.6	6.2	109.1	139.8

*$P < 0.05$ figures in men significantly higher than women.

right collo-diaphysial angle of the femur was significantly higher in men than in women ($p = 0.01$), but there were no significant difference between the left collo-diaphysial angle in the two genders. In Table 1, the maximum femoral head diameter, the minimum femoral neck width and the collo-diaphysial angle of both femurs are presented.

There was no significant difference between the mean of the right and left maximum femoral head diameters in each group ($p > 0.05$). There were also no significant difference between the mean of the right and left minimum femoral neck width in each group ($p > 0.05$). There were no significant difference between the mean of the right and left collo-diaphysial angle in the male group ($p > 0.05$) but this difference was significant in the female group; the mean of the left collo-diaphysial angle was higher than the right side in women ($p = 0.002$).

Because there was a difference between the mean maximum diameters of the femoral head and the minimum width of the femoral neck and right collo-diaphysial angle between the two sexes, demarking point values were calculated using ROC curves. The sensitivity, specificity, positive and negative predictive values and accuracy in defined demarking points are provided in Table 2, Diagrams 1–5.

There was no significant difference between the maximum diameter of the femoral head, the minimum femoral neck width, and the collo-diaphysial angle on the right and left sides based on the body mass index (BMI) in patients ($p > 0.05$).

We found a direct linear relationship between the height and the maximum diameter of the femoral head and the minimum femoral neck width on the right and left sides in men and women. But there was not any significant linear relationship between height and collo-diaphysial angle in both sexes (Table 3).

4. Discussion

In this study, the mean of the right and left maximum femoral head diameters and the minimum width of the femoral neck were significantly higher in men than in women ($p < 0.001$). This finding is consistent with previous studies [3,5,19,22,23] and as expected, the dimensions of the femoral head in men were higher than in women. These differences may be explained by the larger physique of men which is discussed in previous studies.[3,5,19,22,23]

In our study, the right collo-diaphysial angle in men was significantly larger than women ($p < 0.05$). Some studies have mentioned that the smaller collo-diaphysial angle in women can be due to a wider pelvis, larger bi-condylar angle (deviation of the femur shaft), and shorter length of the femur.[13]

Previous studies evaluated the collo-diaphysial angle in different populations and ethnic groups such as Indian,[4,26] Norwegian,[27] Danish,[3] Brazilian,[5] Malaysian,[25] Nigerian,[24] Kenyan and Ugandan.[2] Each region has its own characteristics and racial diversity in the collo-diaphysial angle.[2–5,24–27] Table 4 compares the collo-diaphysial angle measurements obtained in this study with previous studies.

The mean collo-diaphysial angle obtained in this study was higher than some previous studies, such as a study conducted in Malaysia[25] and less than others such as studies performed in Africa[2,24] and Europe.[3] Our findings are consistent with a study conducted in India.[26] These diversities further emphasize the regional and racial differences. No study has addressed the collo-diaphysial angle in the Iranian population. Therefore, there was no previous data for comparison in our country.

A comparison of our findings with the results of the Tahir et al. study in Nigeria,[24] the Igbigbi study in Uganda and Kenya[2] and the Nissen study in Denmark[3] showed that the mean of the collo-diaphysial angle was higher in those regions. This could be due to the larger physique of people in those countries. The mean of collo-diaphysial angle in our study was the same as findings in India[26] and Malaysia[25] and was less than the mean of the collo-diaphysial angle in women in these studies.[3,24,25] As previously mentioned, femoral morphometric parameters in each region are unique to the region while the racial factors and body size have an impact on these parameters.

The mean of the left collo-diaphysial angle was higher in men than in women. However, this difference was not statistically significant ($p = 0.24$). It might be due to the finding that the angle on the left side was significantly larger than the right side in women which can cause similar results in the calculations of the collo-diaphysial means in men and women. Additional studies with a larger sample size and limiting the study to a comparison of the left and right sides are essential.

Table 2
Sensitivity, specificity, positive and negative predictive values, and accuracy of femoral head parameters in sex determination in studied samples.

	Right max femoral head diameter	Left max femoral head diameter	Right min femoral neck width	Left min femoral neck width	Right collodiaphysial angle
Gender discrimination range	56.9	56.1	38.1	37.8	127.95
Sensitivity	56	59	56	59	51
Specificity	98	97	98	96	67
Positive predictive values	96.6	95.2	96.6	93.7	60.7
Negative predictive values	69	70.3	69	70.1	57.8
Accuracy	77	78	77	77	59

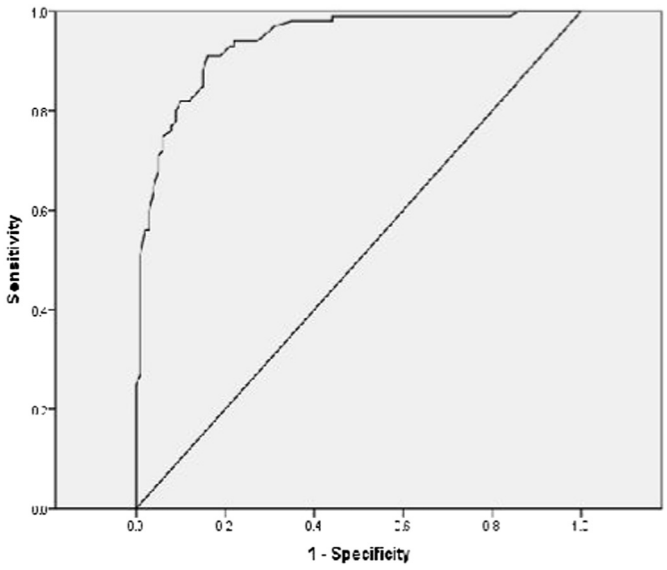

Diagram 1. Roc curve of predictive power of right maximum femoral head in determining the sex.

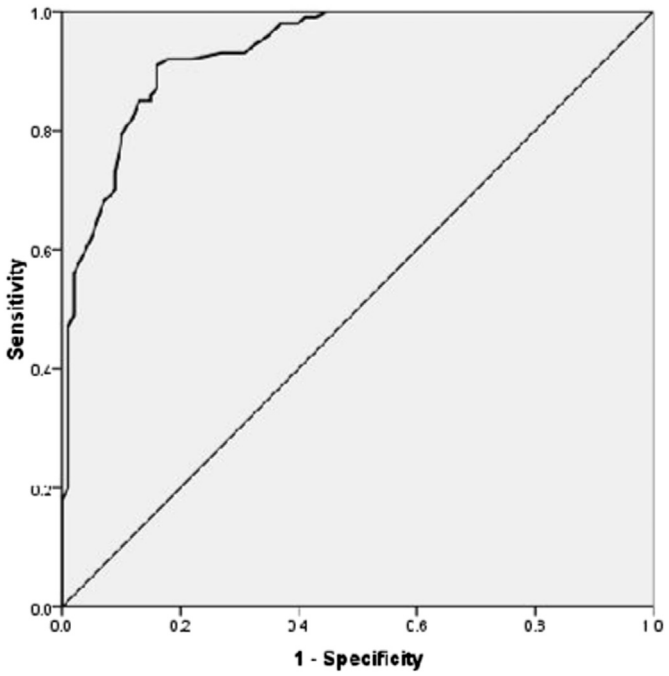

Diagram 3. Roc curve of predictive power of right minimum femoral neck width in determining the sex.

In our study, the accuracy of this angle in sexing was not very high. We found that in our study, sensitivity, specificity, accuracy, positive and negative predictive values of right collo-diaphysial angle for the diagnosis of the male gender in the demarking point of 127.95, were 51%, 67%, 59%, 60.7% and 57.8%, respectively. In the Igbigbi study[25] sexing in Malawian samples with the demarking point method was impossible which was also found to be the case in the Igbigbi's study of the Kenyan and the Ugandan population[2] by using the demarking method, only 19% of Ugandan women, 41.7% of Kenyan men and 18.2% of Kenyan women were diagnosed. Knight considered the acute angle of the neck on the shaft of the femur as the collo-diaphysial angle and claimed that if the bone had an angle of less than 40° it had an 85% chance of being male, and if the angle was larger than 50°, there was a 75% chance for being from a female.[1]

In our study, maximum femoral head diameter and minimum femoral neck width had a high accuracy in gender determination (78% and 77% respectively). This figure is inconsistent with previous studies.[3,5,22] In our study, areas under the ROC curves for maximum femoral head diameter and minimum femoral neck width were significantly higher than areas for collo-diaphysial angle (94–95%

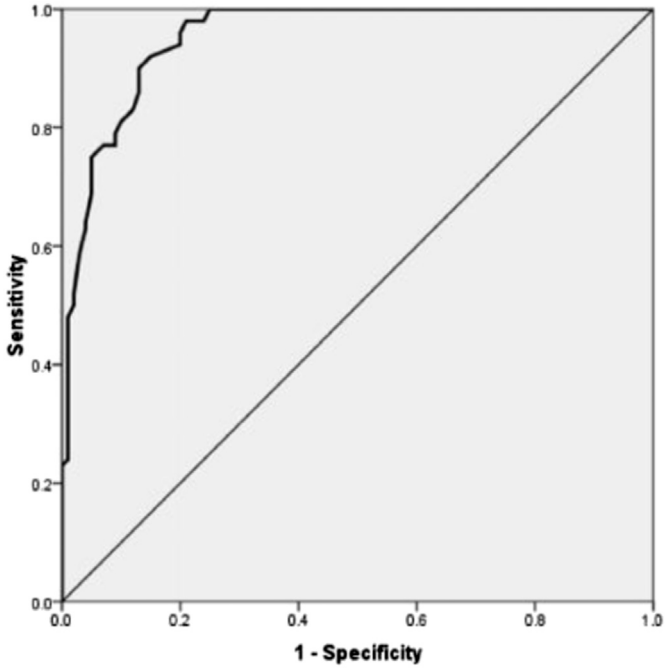

Diagram 2. Roc curve of predictive power of left maximum femoral head in determining the sex.

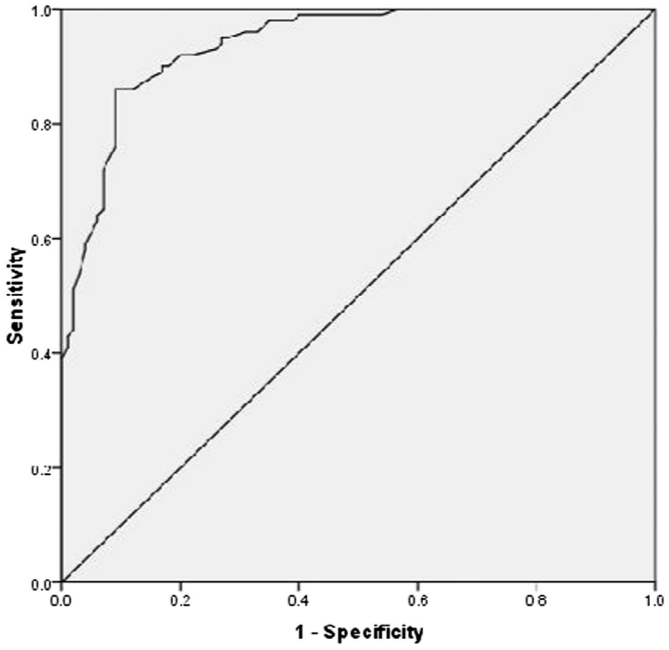

Diagram 4. Roc curve of predictive power of left minimum femoral neck width in determining the sex.

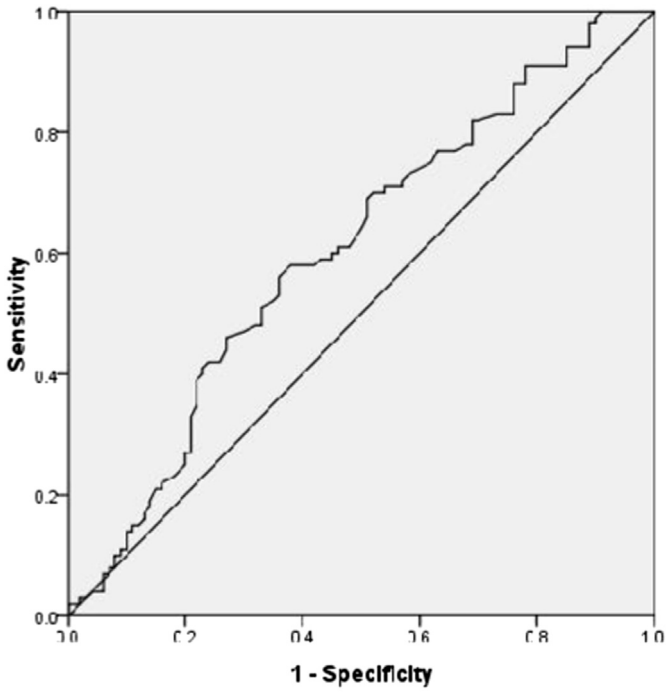

Diagram 5. Roc curve of predictive power of right collo-diaphysial angle in determining the sex.

and 93–94% compared to 53–60% respectively). This shows a great accuracy for sexing by using these two variables. We found that except for a significant difference in the collo-diaphysial angle of women, other measures showed no significant differences in the left and right side.

In a study conducted in Brazil[5], there was no significant difference between measured morphometric parameters on both sides. In this study, the left Collo-diaphysial angle was significantly higher than the right side in women (126.6 ± 6.2 at left vs. 125.4 ± 6 at right) ($p = 0.002$). This shows the need for further studies with a larger sample size to address this difference as well as evaluating the possible factors influencing it in the Iranian population. Is should also be noted that although this small difference is statistically significant (about 1°), it might not be helpful and readily measurable in practice.

Table 3
Comparison of the measured femoral head parameters in both genders based on height.

	Male		Female	
	Correlation coefficient	*P* value	Correlation coefficient	*P* value
Right maximum femoral head diameter (mm)*	0.39	<0.001*	0.35	<0.001*
Right minimum femoral neck width (mm)*	0.36	<0.001*	0.32	<0.001*
Right collo-diaphysial angle (°)*	0.02	0.82	−0.005	0.96
Left maximum femoral head diameter (mm)*	0.39	<0.001*	0.25	0.01*
Left minimum femoral neck width (mm)*	0.33	<0.001*	0.29	0.004
Left collo-diaphysial angle (°)	0.03	0.73	−0.09	0.33

*$P < 0.05$ linear relationship was seen between figures and height in both sexes.

Table 4
Comparison of collo-diaphysial angle in different countries and sub-division.

Authors	Method	Population (year)	Sub-division		Collo-diaphysial angle
This study	Radiography	Iran (2012)	Male	Right	127.5 ± 5.3
				Left	127.6 ± 5.6
			Female	Right	125.4 ± 6
				Left	126.6 ± 6.2
de Sousa et al.[18]	Radiography	Brazil (2010)	Right		132.1 ± 7.2
			Left		131.8 ± 5.2
Reikeras et al.[25]	Direct	Norway (1982)			127.7 ± 7.6
Isaac et al.[24]	Direct	India (1998)			126.7
Tahir et al.[21]	Radiography	Nigeria (2001)	Male		136.7 ± 3.9
			Female		126.6 ± 3.3
Igbigbi & Msamati[12]	Radiography	Malaysia (2000)	Right		121.09 ± 7.17
			Left		114 ± 5.5
Igbigbi[2]	Radiography	Uganda (2003)	Male		133.4 ± 5.3
			Female		123.4 ± 5.8
		Kenya (2003)	Male		140.2 ± 6.2
			Female		125.7 ± 5.1

The maximum diameter of the femoral head and minimum femoral neck width increased with increasing height in both men and women. There was no linear relationship between height and collo-diaphysial angle in both sex. In a study by Nissen et al.[3] the collo-diaphysial angle of the femur was associated directly with height and inversely with weight. It was only reported in women, whereas in men, the diameter of the femoral head was directly associated with weight.

There were no significant differences between the maximum diameter of the femoral head, minimum femoral neck width, and collo-diaphysial angle on the right and left sides based on the body mass index (BMI) in patients ($p > 0.05$). According to previous studies,[3] since these factors are directly associated with height and inversely associated with weight, the collo-diaphysial angle might not show a significant association with BMI. Another explanation could be due to weight fluctuations throughout life and during angle formation.

5. Conclusion

This study found a significant difference between men and woman in the collo-diaphysial angle, the maximum femoral head diameter and the minimal femoral neck. Based on the results of this study we conclude that the maximum femoral head diameter and the minimal femoral neck provide useful and reliable parameters for sexing, whereas the practical value of the collo-diaphysial angle is more ambiguous. The results are not expansible to other populations, direct measurements and measurements before the onset of puberty.

Ethical approval
None declared.

Funding
None declared.

Conflict of interest
Nil.

Acknowledgment

This study was part of Dr. Vida Allahyar Parsa's dissertation to get specialized degree in Forensic Medicine. We are grateful for

funding from vice chancellor of research of Tehran University of Medical Sciences.

References

1. Saukko P, Knight B. *Knight's forensic pathology*. 3rd ed. London: Arnold; 2004. pp. 106–13.
2. Igbigbi PS. Collo-diaphysial angle of the femur in east African subjects. *Clin Anat* 2003;**16**:416–9.
3. Nissen N, Hauge EM, Abrahamsen B, Jensen JEB, Mosekilde L, Brixen K. Geometry of the proximal femur in relation to age and sex: a cross-sectional study in healthy adult Danes. *Acta Radiol* 2005;**5**:514–8.
4. Unnanuntana A, Toogood P, Hart D, Cooperman D, Grant RE. Evaluation of proximal femoral geometry using digital photographs. *J Orthop Res* 2010;**28**: 1399–404.
5. de Sousa EB, Pacheco Fernandes RM, Mathias MB, Rodrigues MR, Ambram AJ, Babinski MA. Morphometric study of the proximal femur extremity in Brazilians. *Int J Morphol* 2010;**28**:835–40.
6. Felt WJL. The prenatal developments of the human femur. *Am J Anat* 1954;**94**: 1–44.
7. Lofgren L. Some anthropometric anatomical measurements of the femur of Finns from the viewpoint of surgery. *Acta Chir Scand* 1956;**110**:479–84.
8. Lusted LB, Keats TE. *Atlas of roentgenographic measurements*. 4th ed. Chicago: Year Book Medical Publishers; 1996. pp. 165–6.
9. Singh SP, Singh S. Collo-diaphyseal angle of the femur in North Indians. *Indian Med Gaz* 1975;**15**:11–4.
10. Gulan G, Matovinovic D, Nemec B, Rubinic D, Ravlic-Gulan J. Femoral neck anteversion: value, development, measurement, common problems. *Coll Antropol* 2000;**24**:521–7.
11. Hefti F. Deviations in the axes of the lower extremities. *Orthopade* 2000;**29**: 814–20.
12. Alonso GG, Guriel MD, Carranza FH, Cano RP, Perez AD. Femoral bone mineral density, neck-shaft angle and mean femoral neck width as predictors of hip fracture in men and women. *Osteoporos Int* 2000;**11**:714–20.
13. Singh SP, Ekandem GJ, Ani OEO, Onuba O. A study of the collo-diaphyseal angle of the femur in Nigerians. *West Afr J Anat* 1986;**1**:28–32.
14. Igbigbi PS, Kwatampora J. Lower limb angles of east African subjects. *West Afr J Anat* 1997;**5**:9–15.
15. Igbigbi PS, Msamati BC. Sex determination from femoral head diameters in black Malawians. *East Afr Med J* 2000;**77**:147–51.
16. Kate BR. The angle of the femoral neck in Indians. *East Anthropol* 1967;**10**:54–60.
17. Keats TE, Teeslink R, Diamond AE, Williams JH. Normal axial relationships of the major joints. *Radiology* 1996;**87**:904–7.
18. Zhang H, Hu YQ, Zhang ZL. Age trends for hip geometry in Chinese men and women and the association with femoral neck fracture. *Osteoporos Int* 2011;**22**(9):2513–22.
19. Bagaria V, Deshpande S, Kuthe A, Rasalkar DD, Paunipagar BK, Madhugiri TS. Radiographic study of the hip joint to determine anthropometric parameters for Indian population. *Eur J Radiol* 2012;**81**(2):312–6.
20. Akhlaghi M, Moradi B, Hajibeygi M. Sex determination using anthropometric dimensions of the clavicle in Iranian population. *J Forensic Leg Med* 2012;**19**: 381–5.
21. Akhlaghi M, Sheikhazadi A, Ebrahimnia A, Hedayati M, Nazparvar B, Saberi Anary SH. The value of radius bone in prediction of sex and height in the Iranian population. *J Forensic Leg Med* 2012;**19**:219–22.
22. Srivastava R, Saini V, Rai RK, Sh Pandey, Tripathi SK. A study of sexual dimorphism in the femur among north Indians. *J Forensic Sci* 2012;**57**:19–23.
23. Sembian Umapathy, Muhil M, Srimathi T, Muthukumar T, Nalina Kumari SD. A study of sexual dimorphism in femora of rural population of south Tamilnadu, India. *J Clin Diagnosis Res* 2012;**6**:163–5.
24. Tahir A, Hassan AW, Umar IM. A study of the collodiaphyseal angle of the femur in the north-Eastern Sub-Region of Nigeria. *Niger J Med* 2001;**10**:34–6.
25. Igbigbi PS, Msamati BC. The femoral collodiaphyseal angle in Malawian adults. *Am J Orthop (Belle Mead NJ)* 2002;**31**:682–5.
26. Isaac B, Vettivel S, Prasad R, Chandi G. Prediction of the femoral neck-shaft angle from the length of the femoral neck. *Clin Anat* 1998;**10**:318–23.
27. Reikeras O, Hoiseth A, Reigstad A, Fonstelien E. Femoral neck angles: a specimen study special regard to bilateral differences. *Acta Orthop Scand* 1982;**53**: 775–9.